The Show Must Go On

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Booming sound waves of contemporary country music permeated the Indiana State Fair grounds on August 13, 2011, as a massive, severe thunderstorm rolled in. The temporary, seemingly stable performance stage stood strongly in the wind as people cheered along to the music duo Sugarland's mellow tunes. The winds picked up, however, and the stage began tumble under the band's feet. The collapse of the stage killed seven people and injured several others (Chapman 2012). To put it simply, the stage was not built to withstand such a severe thunder and wind storm that hit Indianapolis that day. According to Eyewitness News writer Sandra Chapman, "The stage had grossly inadequate capacity to resist both the minimum-code specified wind speed and the actual wind speed that was present at the time of the failure" (Chapman 2012). In engineering, design typically focuses on certain points in the structures. Engineers take into account all of the forces present at each of these points. Structures that are able to remain still and stable on the ground *do*, indeed, have several forces acting upon them. The structures are able to maintain their stability when the sum of all the forces in all directions is equal to zero. This is a common engineering term known as *equilibrium* (Bolton, Kraige, & Meriam 2015). The stage was incapable of resisting the force that the wind caused, and furthermore, collapsed. Because the storm was unanticipated, the engineers weren't completely at fault; however, notable factors that went into the erection of the stage certainly could be considered causation for its failure.

Figure 1 (below) is a typical schematic, or *free body diagram* (Bolton, Kraige, & Meriam 2015), that engineers would use to explain the collapse. All of the arrows represent forces acting on the body. It is apparent that the force of the wind came from the west and there was no opposing force to counteract it, or keep it in *equilibrium*. The upper portion of stage (labeled *lateral load resisting system*) also has several forces attached to it. These forces are due to the weight, or the *gravitational forces*, of the roof and associated entertainment equipment, such as the speakers and spotlights. The same sort of force can be found along the bottom of the stage. Labeled also are the *wire rope guy lines*, which were the horizontal supports for the structure. According to the Tomasetti report, the guy lines experienced about 20 times more force from the wind than they were designed to hold (Tomasetti 2012). Ultimately the lines were not strong enough to counteract the forces of the wind.

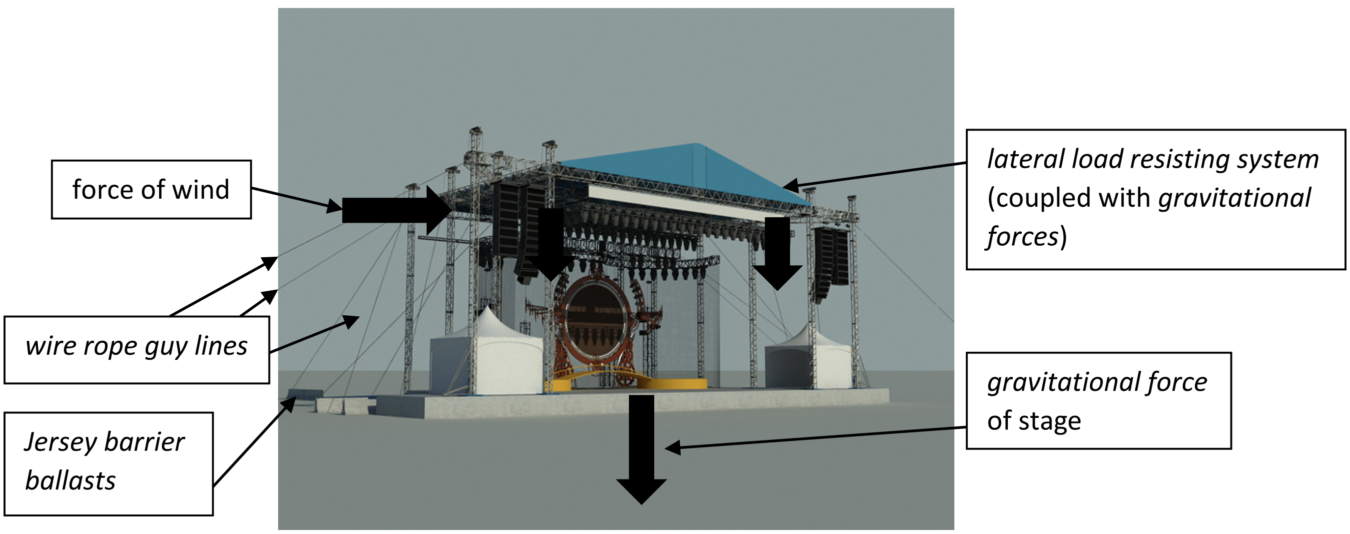

Figure 1: A schematic of the stage before its collapse (Tomasetti 2012).

The failure of the stage amassed several ethical implications, such as the materials utilized to build it and the quality of inspection that it went under prior to the concert. People also questioned as to why no evacuation was initiated at the announcement of the storm. When investigation began, people were appalled at the lack of concern that occurred during the erection of the stage. For starters, no expert inspection was held after the stage was built. According to the engineering report of the collapse, “There is no evidence of an engineering review of the ‘2011 Sugarland Rigging Plot’ by a licensed design professional prior to August 13, 2011” (Tomasetti

2012). The materials and design also were at fault; according the Tomasetti report, the failure was due to the “inadequate capacity of the lateral load resisting system.” The *lateral load resisting system* refers to the top of the structure, which was attached to wire rope guy lines. The guy lines were similar to the relatively harder cables used to support an everyday camping tent. It is assumable that these lines did not have the strength to support the top of the stage, due to their ability to snap. The guy lines were attached to *Jersey barrier ballasts* surrounding the perimeter of the stage. *Jersey barrier ballasts* are triangular, heavy ground supports that attach to lines, and use gravitational force to hold everything in place. The incident report mentions that the people who erected the stage did not completely understand the support that the ballast-guy line combination provided was not enough to stabilize the lateral load resistance system (Tomasetti 2012). It was later deemed obvious that the stage wasn’t engineered properly because other constructions, including an aluminum trailer and a Ferris wheel (which was placed only fifty yards away from the stage), surrounding it remained unscathed after the storm had passed (Associated Press 2011). Fair officials later professed that they “began to prepare for” but never mentioned an evacuation (Associated Press 2011). The combination of the overloaded roof, faulty materials, a lack of inspection, and poor management led to the ultimate recipe for disaster.

Duke University Professor Henry Petroski penned an article for *The New York Times* discussing the importance of “defensive engineering” in structural design. In this text, he impeccably explains the extreme significance of engineers’ recognition of failure. According to Petroski, the best way to create a failure-free design is to imagine everything that could go wrong with it, and fix those discrepancies (Petroski 2003). “Until it fails,” he writes, “how far beyond design conditions a system can be pushed is never fully known” (Petroski 2003). In the case of the Indiana State Fair concert stage, the builders were completely unaware of how much wind speed it could withstand. In fact, the builders barely had an idea how much horizontal force the top of the stage would be able to counteract (Tomasetti 2012). The stage began to struggle under 33 mile-per-hour winds, and collapsed at 60 mile-per-hour winds (Chapman 2012). Nobody had anticipated the collapse, especially at a state-funded event such as the fair. “Operating conditions cannot be predicted with absolute certainty,” says Petroski. Even though the storm could not have been foreseen, the engineers did not follow several codes of construction regarding defense against wind. According to the report, the engineers did not follow the codes because they did not completely understand the weight distribution over the whole structure, or the amount of force wind could possibly apply if there was any (Tomasetti 2012). Ultimately, the goal of engineering is to mesh the arts and sciences to create structures to benefit all people, and do so in the most ethical and efficient way in their capacity. They first need to have a complete understanding of every detail that goes into their designs. They need to be assured that under unusual circumstances, such as a treacherous thunderstorm, their structures will remain stable. Engineers must be responsible for testing all possible failures that can occur within the design. Because no professionals inspected the stage after its completion, there was obviously no tests for possible faults, which led to its demise.

The collapse of the stage certainly was a tragedy; however, it did lead to improvements in legislature about the construction of temporary structures. After the disaster, the State of Indiana prompted new laws regarding stage inspections. The people affected spoke out about those they lost or the injuries they experienced. In 2014, three years following, a $50 million settlement was reached with the state of Indiana to cover damages, lives lost, and injuries inflicted (Botelho

2014). Although the collapse of the stage was a terrible event, it gave light to the importance of assuring that any structural design used by the public must be virtually failure-free.

Resources

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